Electronic Version
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Claims

[c1] 1.An oscillator inverter circuit comprising:

a first crystal node and a second crystal node that are for coupling across a crystal oscillator;

a plurality of current sources generating source currents that are relatively insensitive to changes in a power-supply voltage including an amplifier source current and an output source current;

a low-gain input stage having a gate on the first crystal node and outputting a buffered node buffered from the first crystal node;

a gain stage having a converter transistor that receives the buffered node on a gate and generates a varying current that varies with voltage variations of the first crystal node;

a current mirror that receives a current difference of the amplifier source current and the varying current, the current mirror generating a mirrored voltage by mirroring the current difference; and

an output stage that receives the output source current and the mirrored voltage, with an output transistor that has a gate driven by the mirrored voltage and is connected to the second crystal node,

whereby the varying current is mirrored by the current mirror to control driving of the second crystal node by the output stage.

[c2] 2.The oscillator inverter circuit of claim 1 wherein the low-gain input stage further comprises:
an input resistor coupled between the first crystal node and the buffered node, the input resistor having a resistance sufficient to block oscillating signals from the crystal oscillator, but passing bias voltages.

[c3] 3.The oscillator inverter circuit of claim 2 wherein the input resistor has a resistance of at least 200 K-ohms.

[c4] 4.The oscillator inverter circuit of claim 2 wherein the current mirror comprises:
a combining node that combines the amplifier source current and the varying current to generate the current difference;
an amplifier transistor that passes the current difference through a channel, and has a gate connected to the combining node;
a first mirror transistor having a gate connected to the combining node, for generating a mirrored current; and
a second mirror transistor having a channel in series with a channel of the first mirror transistor, the second mirror transistor having a gate and a drain connected together

to generate the mirrored voltage.

[c5] 5.The oscillator inverter circuit of claim 4 wherein the output stage further comprises:
a pull-up transistor that receives a first portion of the output source current, the first portion being conducted by a channel of the pull-up transistor to the second crystal node;
wherein a second portion of the output source current is received by the first mirror transistor.

[c6] 6.The oscillator inverter circuit of claim 1 wherein the low-gain input stage comprises an input transistor having a drain connected to the buffered node and a gate connected to the first crystal node;
wherein the buffered node receives an input source current from the plurality of current sources;
wherein the converter transistor is a n-channel transistor that receives the buffered node on a gate and a drain at a combining node and a grounded source;
wherein the combining node receives the amplifier source current;
an upper amplifier transistor in the current mirror, having a drain connected to the combining node, a gate connected to the combining node, and a source connected to an intermediate node;
a lower amplifier transistor in the current mirror, having

a drain connected to the intermediate node, a gate connected to the mirrored voltage, and a source connected to a ground;

an upper current mirror transistor having a drain connected to an output-source node receiving the output source current, a gate connected to the combining node, and a source connected to the mirrored voltage;

a lower current mirror transistor in the current mirror, having a drain connected to the mirrored voltage, a gate connected to the mirrored voltage, and a source connected to the ground;

wherein the output transistor has a drain connected to the first crystal node and a source connected to the ground.

[c7] 7.A current-mirrored crystal oscillator comprising:

a crystal, coupled between a first node and a second node, that oscillates at an oscillation frequency when connected to a gain inverter;

a bias resistor coupled between the first and second nodes, for biasing the first and second nodes to an intermediate voltage;

a gain inverter, having an input driven by the first node, for driving the second node to induce oscillation by the crystal, wherein the gain inverter comprises:

an input transistor having a gate connected to the first

node and a drain driving a buffered node;
a converter transistor having a gate connected to the buffered node, for generating a varying current that varies with small-signal variations on the first node;
a current mirror, coupled to mirror changes in the varying current to generate a mirrored node; and
an output stage, responsive to the mirrored node, for driving an output current from the second node,
whereby the small-signal variations on the first node are buffered, converted to the varying current, and mirrored to drive the output current from the second node.

[c8] 8.The current-mirrored crystal oscillator of claim 7 wherein the current mirror comprises:
a first amplifier transistor having a gate connected to the mirrored node, and receiving an amplifier current that varies with the varying current; and
a first current mirror transistor having a gate and a drain connected to the mirrored node, for biasing the mirrored node.

[c9] 9.The current-mirrored crystal oscillator of claim 8 wherein the current mirror further comprises:
an amplifier node connected to receive the varying current from the converter transistor;
a second amplifier transistor having a gate and a drain connected to the amplifier node, the second amplifier

transistor having a channel in series with a channel of the first amplifier transistor; and

a second current mirror transistor having a gate connected to the amplifier node, the second current mirror transistor having a channel in series with a channel of the first current mirror transistor.

[c10] 10.The current-mirrored crystal oscillator of claim 9 wherein the output stage comprises:

an output transistor having a gate connected to the mirrored node and a drain connected to the second node;

a pull-up transistor having a gate and a drain connected to the second node, and a source connected to the channel of the second current mirror transistor.

[c11] 11.The current-mirrored crystal oscillator of claim 10 wherein the output stage further comprises:

an output current source connected to a drain node that connects to the channel of the second current mirror transistor and connects to the source of the pull-up transistor.

[c12] 12.The current-mirrored crystal oscillator of claim 11 further comprising:

a source resistor, connected between a channel of the converter transistor and a ground.

[c13] 13.The current-mirrored crystal oscillator of claim 9 further comprising:
an amplifier current source, connected to the amplifier node, for sourcing current to the amplifier node and to the converter transistor and to the second amplifier transistor.

[c14] 14.The current-mirrored crystal oscillator of claim 13 further comprising:
an input current source, connected to the buffered node, for sourcing current to the buffered node and to the input transistor.

[c15] 15.The current-mirrored crystal oscillator of claim 8 further comprising:
a parallel transistor, having a gate and a drain connected to the buffered node, for generating a voltage of the buffered node.

[c16] 16.The current-mirrored crystal oscillator of claim 8 further comprising:
an input resistor connected between the first node and the buffered node, for passing direct-current (DC) bias voltages but for blocking small-signal variations in the first node.

[c17] 17.The current-mirrored crystal oscillator of claim 10

wherein the input transistor, the converter transistor, the first amplifier transistor, the first current mirror transistor, and the output transistor are n-channel transistors having sources connected to a ground.

[c18] 18.The current-mirrored crystal oscillator of claim 17 wherein the pull-up transistor is a p-channel transistor.

[c19] 19.A current-mirroring inverter for a crystal oscillator comprising:

input transistor means, receiving a first crystal node at a gate, for conducting a buffered current from a buffered node in response to rapid voltage variations on the first crystal node generated by oscillation of a crystal connected to the first crystal node and to a second crystal node;

converter transistor means, having a gate receiving the buffered node, for conducting a varying current from a combining node in response to the buffered node;

amplifier current source means for generating an amplifier current to the combining node;

first amplifier transistor means, having a gate driven by the combining node, for conducting a difference current from the combining node;

first current mirror transistor means, receiving the combining node at a gate, for conducting a mirrored current;

second current mirror transistor means, having a gate

driven by a mirrored node between channels of the first and second current mirror transistor means, for conducting the mirrored current; and

output transistor means, having a gate receiving the mirrored node, for drawing current from the second crystal node.

[c20] 20.The current-mirroring inverter of claim 19 further comprising:

input resistor means for conducting slow bias voltages from the first crystal node to the buffered node, and for blocking rapid voltage variations on the first crystal node generated by oscillation of the crystal connected;

parallel transistor means, having a gate driven by the combining node, for conducting current from the combining node in parallel to the buffered current through the input transistor means.